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ABSTRACT

A study for a consortium of two-year postsecondary institutions investigated technician training needs in the field of biotechnology. It assessed the need for biotechnicians from 1985 to 1995 and investigated the potential need to develop two-year postsecondary biotechnician curricula. The scope of the project included identification of current and expected applications of biotechnology, identification of potential employers of biotechnicians, establishment of a Biotechnology Task Force on Education to evaluate and interpret study findings, preparation of a preliminary listing of job skills and knowledge required of biotechnicians, and development of a model two-year curriculum in biotechnology. The report contains the listing of biotechnician tasks and a model curriculum. Tentative course descriptions for each course in the curriculum are also provided. Information is presented on tailoring the model curriculum. Appendixes include the survey form, a listing of companies surveyed, a listing of task force members, and survey findings. (YLB)

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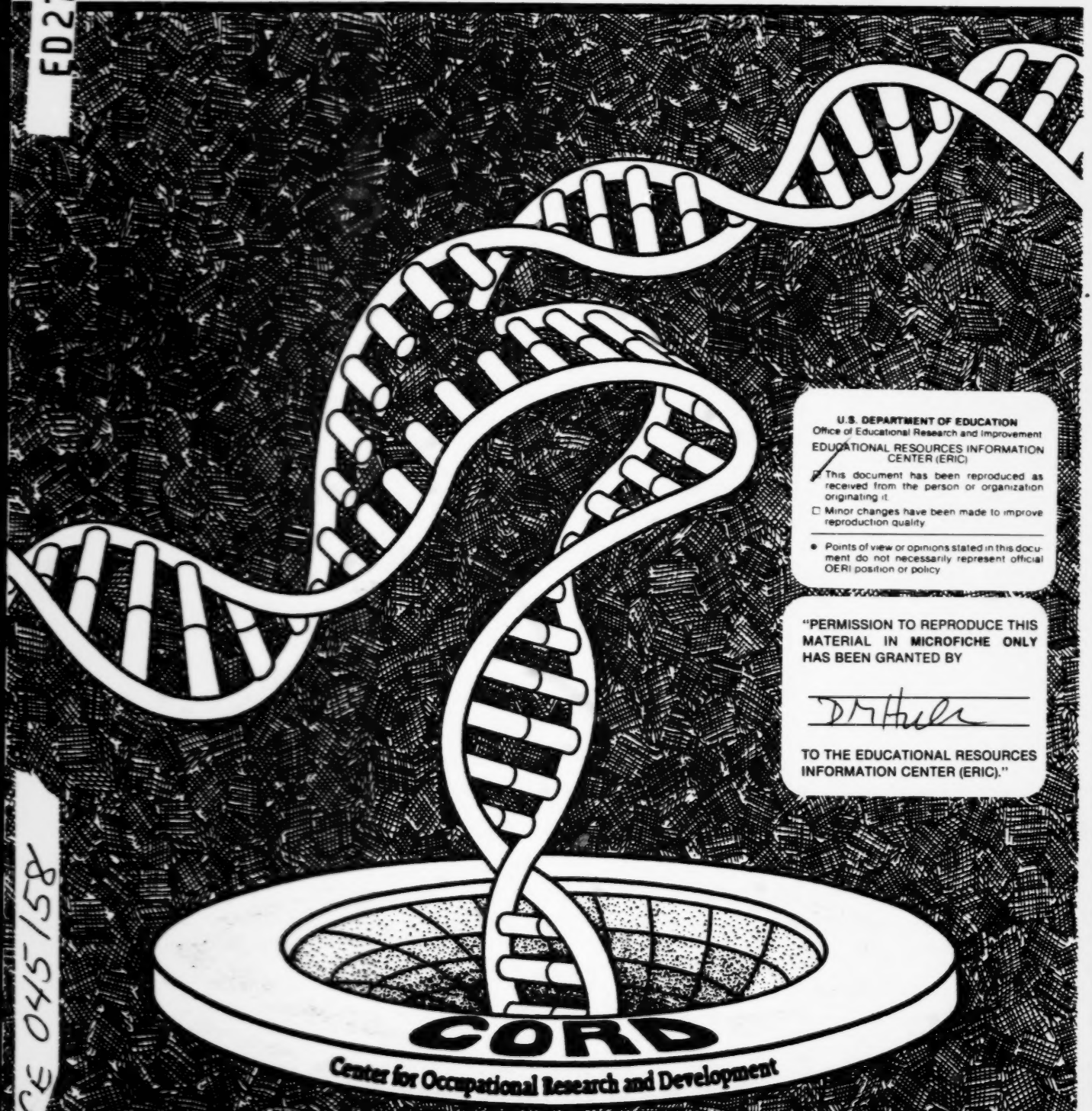

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Education for Biotechnology

Bonnie F. Rinard

The Center for Occupational
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Preface

New technology development usually occurs in four distinct but overlapping phases:

The period of discovery
The period of emergence
The period of applications
The period of exploitation

An examination of six or seven technologies that have matured in this century will reveal that the need for engineering or scientific technicians became evident between the second and third phases or periods. Biotechnology appears to have matured well into the period of emergence and has entered the period of applications. We expect the need for biotechnicians to surface very soon.

Until now, most biotechnicians who work in research and development have been baccalaureate-degreed biologists and chemists. People with this background are abundant in the job market, and they serve well as lab technicians.

However, as large-scale manufacturing begins for new biotechnical products, technicians will require a more diverse, "process control" background to construct, operate and maintain large-volume fermentation processes. Thus, the emergence of a new breed of biotechnicians.

The Center for Occupational Research and Development (CORD) has completed a study for a consortium of two-year postsecondary institutions to investigate technician training needs in the field of biotechnology. The study assessed the projected need for biotechnicians from 1985 to 1995 and investigated the potential need to develop two-year postsecondary biotechnician curricula.

The scope of the project included the following tasks:

- Identification of current and expected applications of biotechnology
- Identification of potential employers of biotechnicians--those organizations that are producing biotechnology research, development and products
- Assessment of present and future needs for biotechnicians
- Establishment of a Biotechnology Task Force on Education to evaluate and interpret the findings of the study
- Preparation of a preliminary listing of job skills and knowledge required of biotechnicians
- Development of a model two-year curriculum in biotechnology

The curriculum proposed in this report is somewhat premature and speculative--as it should be in any emerging technology report. The findings of this study should be used as a starting point for two-year postsecondary educators who are considering establishing biotechnology programs. Further refinement and specification can be accomplished by a team of educators and local and/or regional employers and technical specialists.

Daniel M. Hull, President

Center for Occupational Research
and Development

February 1986

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Lorain County Community College
Macomb Community College
North Central Technical Institute
Sinclair Community College
Texas State Technical Institute
Triton College

Education for Biotechnology

INTRODUCTION

The Commerce Department has defined biotechnology as follows:

> "Biotechnology is a term applied to a group of technologies which uses organisms (or natural or synthetic parts thereof) to make or modify commoditites or provide services."

This study has tentatively defined the biotechnician's role as follows:

> Biotechnicians serve on research, production, or service teams in the fields of human health, agriculture and animal health, energy and environment and the food industry. They serve as skilled assistants supporting professional scientists, engineers and/or managers. Biotechnicians are knowledgeable in applied biological/chemical science, and they are skilled in such techniques, methods and processes as recombinant DNA, cell/tissue culture, fermentation and protein sequencing/synthesis. Biotechnicians usually work under the direction of the professional leaders, but may function with little supervision in performing routine predictable functions.

While this description is based on survey responses and CORD's dialog with the biotechnology industry, it should be regarded as only an initial attempt to describe the role of the biotechnician. A fully adequate job description can be formulated only after more extensive study and evaluation.

BACKGROUND

Biotechnology is experiencing a high-tech revolution equally as exciting as the high-tech revolution in the electronic/electromechanical fields. Much of the impetus for this revolution stems from the products of high-tech advances in the electronic/electromechanical areas such as scanning electron microscopes, biosensors, computers and other highly sensitive and specialized instrumentation. These advances have made it possible to monitor and control biological and chemical processes. Whereas the products of the high-tech revolution in electronics/electromechanics are usually thought of as highly efficient, complex machines such as computers and robots, the products of the biotechnical revolution are often living organisms. These organisms have been selected, modified in many cases, bred and raised to produce an assortment of useful and beneficial substances such as food, drugs and fuels or to perform tasks such as desulfuring coal, cleaning up hazardous wastes, and assisting in the recovery of oil from spent wells.

Figure 1 shows a partial list of applications in four major fields of biotechnology: human health, agriculture and animal health, energy and environment, and food. Many biotechnology procedures and processes find application in all of these areas. Technicians working in these areas will need to know and apply basic principles that are common to all of the fields. This broad-based technology will require technicians trained in relevant, practical applications of biology, chemistry, instrumentation, and computer operation, as well as math and communication skills. To function effectively and stay abreast of the rapidly changing technologies, biotechnicians must be prepared through broad-based training programs that do not emphasize narrow specialties.

Field	Applications
Human Health	New drugs Drug delivery systems Improved drug action Monoclonal antibodies Vaccines Gene therapy for genetic disease Interferon Hormones Other proteins Diagnostics Enzymes Therapeutics
Agriculture/Animal Health	Food additives New and improved plants Vaccines Animal feed supplements Hormones Fertilizers Pesticides/herbicides
Energy and Environment	Biomass Extraction/recovery of metals Chemicals and solvents Algal cultures for photobioreactors Decomposition/detoxification of chemicals Improved microbial systems for environmental control of air, water, and soil Enhanced oil recovery Hydrogen and CO_2 production Coal cleanup (desulfuring)
Food	Preparation/processing Preservation Enhanced nutritional value Additives

Figure 1. New and changing biotechnology fields.

Historically, as emerging technologies have expanded from experimental laboratories and pilot plants to full-scale production facilities, more and more technicians have been required to set up, monitor and maintain the operation. It is anticipated that this trend will also become evident in the biotechnologies; that is, more technicians will be needed than are currently being produced in existing biology-related programs such as agriculture, agronomy, forestry, horticulture, animal science, soils, wastewater treatment, environmental science, energy, and food processing and distribution. It is also anticipated that technicians in biotechnology will be different in important ways from current technicians in other biology fields. The most significant difference is that they will require a broader and more interdisciplinary technical base. As a consequence, many current technicians will require extensive retraining before they are qualified to work in the new biotechnology fields; they will have to learn new techniques, procedures, and instruments.

METHODOLOGY

Data for this study was collected by surveying 242 biotechnology companies. The survey population was limited to companies involved in the biotechnology applications listed in Figure 1: human health, agriculture and animal health, energy and the environment, and food. Two areas often considered part of the biotechnology industry were purposely omitted in the survey: biomedical equipment and prosthetic devices (including both artificial limbs and organs).

Biomedical equipment includes the manufacture, installation, maintenance and repair of equipment used to monitor and/or control living organisms, particularly those of interest to the medical profession. These instruments range from simple instruments such as an electronic thermometer or IV infusion controller to highly sophisticated tools such as positron-emission computed tomograph (PET) and nuclear magnetic resonance (NMR) imagers. Prosthetics are devices that replace body parts, from the cosmetic (glass eyes) to life enhancing (grasping devices to replace missing hands) to life-sustaining devices (the artificial heart).

The fields of biomedical equipment and prosthetics were not included in this survey because they require backgrounds in areas such as electronics, instrumentation and control, fluid and mechanical systems, physics, etc. This study focuses upon those areas of biotechnology that employ techniques that are more specific to biology, such as recombinant DNA, cell fusion, tissue culture and fermentation.

Survey data was collected in two ways: through telephone interviews and written questionnaires. The phone interviews were limited to members of the Industrial Biotechnology Association (IBA). These interviews sought information on the general areas of biotechnology, the direction the industry is moving, and the kinds of technicians that are used. Information also was sought on what biotechnicians should know and on perceived needs for biotechnicians in the future. All phone interviews followed a predetermined structure.

Information from the phone interviews was used to prepare a more detailed written survey (Appendix A). Design of the survey and the later analyses of results were accomplished in collaboration with Dr. Kris Moore, Chairman of Information Systems, Baylor University. This survey was mailed to IBA member companies, to companies listed in the 1984 Office of Technology Assessment Report, Commercial Biotechnology: An International Analysis, and to engineering companies working in biotechnology scale-up projects.

A follow-up letter and second survey form were mailed to all companies that did not respond to the initial mailing within three weeks. By the end of the survey period, ninety-five responses were received, making a response rate of 39%. Nine of these responses did not provide data that could be tabulated. The survey, then, resulted in 86 usable responses, yielding a usable response rate of 36%.

To provide a better breakdown of where the needs for biotechnicians will be greatest, data was tabulated for the United States as a whole and for each of three regions. Appendix B includes a list of states included in each region and a map showing the geographical distribution of companies surveyed. Appendix C lists the companies that were sent the survey forms. Open-ended responses were compiled, sorted and appropriately grouped. A preliminary report summarizing and interpreting the data was then prepared.

A national task force, the Biotechnology Task Force on Education, was formed to review the survey data and to comment on the preliminary report. This task force consists of 24 industry representatives and representatives from 11 two-year postsecondary institutions and state agencies for postsecondary education. Members of the Biotechnology Task Force on Education are listed in Appendix D. Industry representatives were selected based on three main criteria:

- Willingness to serve on the task force
- Geographic location
- Areas of biotechnology involvement

The Biotechnology Task Force on Education met on January 15, 1986, in Chicago. Task force members were asked to clarify and discuss various issues relative to the preliminary report. They were also asked to comment in writing on specific points and to provide more detailed information on job descriptions, production processes, curriculum model and suggestions for other support that schools could provide the biotech industry.

Data summaries and interpretations comprise the remainder of this report.

RESULTS

Response Rates

A total of 242 survey forms were mailed out.

The percentage of companies responding to the survey, by region, is shown below.

From the West: 29.1%
From the Middle States: 20.9%
From the East: 48.2%
No address indicated: 3.5%

The response rate closely paralleled the mailout, as indicated below.

Mailed to the West: 30%
Mailed to the Middle States: 22%
Mailed to the East: 48%

Areas of Involvement

Table 1 shows by region the percentage of companies surveyed that are involved in each of the four areas of biotechnology.

Table 1. Areas of Biotechnology Involvement

	East	Middle	West	Entire USA*
Human Health Care	80%	61%	76%	74%
Agriculture/Animal Health	60%	78%	44%	59%
Energy and Environment	28%	44%	24%	29%
Food	33%	39%	12%	28%

*Entire USA is the percentage of companies surveyed throughout the entire United States that are involved in a particular area of biotechnology.

The frequency of specific products/research areas grouped under the four areas above can be found in Appendix E.

Techniques Used by Companies

A wide variety of biotechnology techniques are used by the companies surveyed. Table 2 lists the percentage of respondents in each region that use each technique.

Table 2. Biotechnology Techniques

	East	Middle	West	Entire USA
Recombinant DNA	65%	78%	68%	69%
Fermentation	63%	89%	52%	65%
Purification	70%	67%	60%	66%
Hybridoma and Cell Fusion	55%	44%	48%	49%
Cell and Tissue Culture	78%	61%	72%	72%
Enzymology	60%	78%	36%	55%
Separation	60%	83%	56%	64%
Sequencing	53%	61%	52%	55%
Synthesis	53%	61%	48%	52%
Other	3%	6%	4%	4%

Scientists and Technicians Currently in R & D and Production

The numbers of scientists and technicians currently working in biotechnology research and development and in biotechnology production are shown in Table 3 below.

Table 3. Scientists and Technicians Working in Biotechnology.

	Biotechnology Research and Development	Biotechnology Production
PROFESSIONAL SCIENTISTS	6205	1311
TECHNICIANS	6204	2239

Projected Need for Biotechnicians

The current number of technicians working in biotechnology and the projected needs for biotechnicians for 1987, 1990 and 1995 are presented in Table 4. The figures shown apply to the entire survey population of 242 companies. This data was extrapolated from the 86 survey responses.

Table 4. Cumulative need for Biotechnicians

	1985	1987	1990	1995
Total USA*	8,443	11,457	14,257	20,981
East	2,928	5,093	5,997	10,290
Middle	1,645	1,958	2,588	2,844
West	3,876	4,078	6,091	8,562

*The total number of technicians in the USA is not equal to the sum of technicians in the east, west and middle because there were several respondents who did not indicate who they were or where they were located.

The number of new technicians needed by 1987, 1990 and 1995 are summarized in Table 5.

Table 5. New Biotechnicians Needs

	by 1987	by 1990	by 1995
Total USA	3,014	5,814	12,538
East	2,165	3,069	7,362
Middle	313	943	1,199
West	202	2,215	4,686

Traits of Biotechnicians

The abilities/aptitudes/characteristics required of technicians are listed below in the order of importance indicated by survey respondents.

Laboratory skills
Works well in a team
Works independently
Technical knowledge
Supervisory and management skills
Highly specialized*
Experience*

*Areas of specialization and experience are listed in Appendices F and G.

Math Requirements

Math requirements for biotechnicians are ranked below by percentage of companies that identified a particular level as being important.

Basic math skills	76%
Algebra	70%
Geometry	16%
Trigonometry	19%
Precalculus	34%
Calculus	22%

Tasks Performed by Biotechnicians

Respondents indicated that the tasks listed below are performed by biotechnicians. The tasks are ranked by the percentage of companies that use technicians for each task.

Prepare samples	95%
Prepare reagents and solutions	94%
Use sterile techniques	92%
Set up lab apparatus	88%
Collect samples	88%
Analyze samples	86%
Prepare culture media	83%
Collect and process data	78%
Use a computer	74%
Operate equipment*	63%
Calibrate equipment*	62%
Clean glassware	59%
Interpret data	52%
Maintain equipment*	29%
Program a computer	16%
Others	6%

*A listing of specific equipment to be operated, calibrated and maintained is found in Appendix H.

Current Education Requirements for Biotechnicians

Respondents to the survey reported that their companies currently expect biotechnicians to have attained the following education levels.

High School	5%
AAS (2-year)	16%
BS/BA	56%
MS/MA	19%
PhD	2%

It should be pointed out that expectations related to education level are shaped by current education offerings. Few two-year biotechnician training programs yet exist.

Future Hiring

Respondents indicated their interest in hiring biotechnicians from two-year postsecondary programs by answering the following question. "In future hiring would your company consider two-year postsecondary graduates from a biotechnology curriculum?"

Yes	17%
Maybe	38%
No	43%
No response	2%

It must be kept in mind that biotechnology companies' present attitudes toward hiring two-year graduates are influenced by the fact that the biotech industry in general has no experience with qualified two-year graduates.

INTERPRETATIONS

National Need for Biotechnicians

Nationwide need for technicians is growing steadily. Of the companies responding to the survey, 64% indicated that they had increased the number of biotechnicians employed over the past two years, while only 1% (one company) reported a decrease in biotechnicians over the same period.

Figure 2 is a plot of the projected number of technicians needed over the 10-year period from 1985 to 1995. Plotting the number of technicians in 1985, 1987, 1990 and 1995 yields a near straight-line growth. By 1995, 12,538 new biotechnicians will be needed. This is equivalent to the addition of approximately 1250 new technicians to the work force each year.

The growth rate for the 10-year period from 1985 to 1995 can be calculated by the following formula.

$$\frac{\text{biotechs needed in 1995} - \text{current biotechs}}{\text{current \# of biotechs}} \times 100\% = \%\ \text{increase}$$

$$20{,}981 - 8443 \div 8443 \times 100\% = 148.5\%\ \text{increase}$$

The 12,538 new technicians needed by 1995 equates to a growth rate of 148% for the 10-year period.

The growing need for biotechnicians relates to the fact that many companies have entered the field of biotechnology only relatively recently and their continued growth is predicted. Over half of the companies surveyed have been involved in biotechnology for less than five years; 75% of the companies surveyed have been working in biotechnology for less than 10 years.

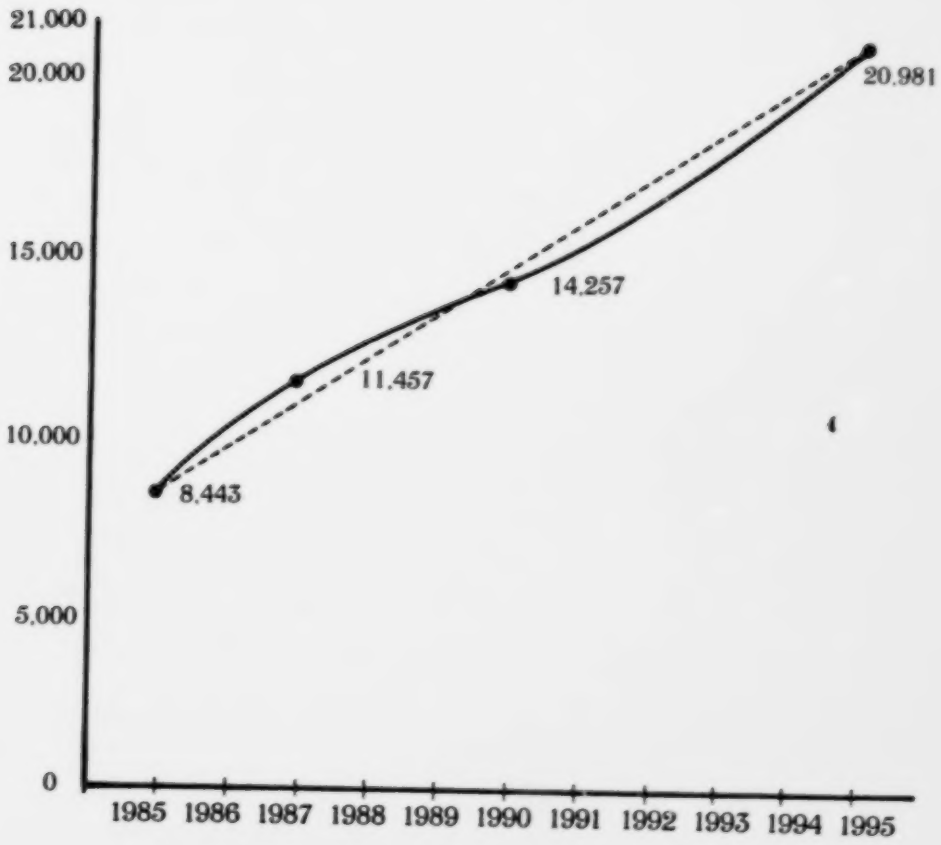

Figure 2. Predicted need for biotechnicians.

The projected need for 12,538 new technicians in the United States by 1995 is based only on the 242 companies that were sent surveys. Many other companies were not included in the survey. The November-December 1986 issue of Genetic Engineering News, for example, listed 177 US companies involved in biotechnology that were not included in this survey. These biotech companies can be expected to experience growth rates similar to those of the companies that were surveyed.

Industry representatives on the Biotechnology Task Force on Education urged caution when viewing the projected needs figures. All representatives agreed that the need for technicians is growing, but they cautioned that the growth may not be as rapid as the survey figures indicate. They said that advances in instrumentation for work such as the sequencing and synthesis of various proteins might tend to flatten the growth curve somewhat. They also indicated that since the biotechnician with a two-year degree will be most readily accepted in the production phase of their work, and because most biotech companies have not yet entered that phase, the time frame may be extended. Biotech products, especially the earliest ones, will require extensive testing before they will be approved by various government agencies for general usage and production.

Regional Need for Biotechnicians

To help schools in specific regions determine whether they should consider establishing biotech training programs, this study divides the country into three regions: East, Middle States and West. The greatest concentrations of biotech companies are located in the Northeast and in California. A much smaller and less concentrated group of biotech firms is found in the area around Chicago and in states bordering the Great Lakes.

Projected growth rate for the three regions over the 10-year period from 1985 to 1995 is as follows:

East 10,290 − 2928 ÷ 2928 × 100% = 251%
Middle 2844 − 1645 ÷ 1645 × 100% = 72%
West 8652 − 3876 ÷ 3876 × 100% = 121%

Using a straight-line projection, one can predict an annual need for each area. In the East the need is for 735 new technicians a year; in the Middle United States the need is for 120 new technicians a year; and in the West, the need is for 480 new technicians a year.

Acceptance of Two-Year Programs

Fifty-five percent of the survey respondents indicated that they would hire or would consider hiring technicians from two-year biotechnician training programs. Forty-three percent of the respondents indicated that they would not hire graduates from two-year biotechnician training programs.

Reasons given for not hiring two-year technicians are included in Appendix I. The majority of the reasons can be categorized as follows.

- There is an oversupply of BS/MS-degreed biologists who will do technician work.
- Two-year programs lack the breadth and depth of four-year programs.
- Students at two-year schools are not as intelligent as those at four-year schools.
- Companies need the research background found in BS/MS programs.

Industry representatives at the Biotechnology Task Force on Education meeting indicated that the industry as a whole is predominantly in a research and development mode. The industry generally believes that for R & D, workers should have bachelor's degrees as a minimum. Since there is currently an oversupply of BS/MS biologists and chemists, there is little incentive for considering hiring AAS-degreed workers. The representatives noted that future hiring plans are usually based on current hiring practices. Consequently, biotechnology companies, at this time, most commonly plan on hiring workers with four-year degrees rather than two-year degrees.

As new products are approved and companies move into the production phase, there will be a greater need for two-year-degreed individuals to operate and maintain the production process and to perform the quality control functions required to ensure product purity and yield. While these activities are critical and must be carried out precisely, they are routine activities. The industry representatives pointed out that several companies are now in the process of running clinical trials and applying for approval to market various items.

Another factor deserving consideration in industry's reluctance to hire two-year graduates is the scarcity of programs designed specifically to meet the needs of the biotechnology industry. Probably the closest two-year programs are industrial biology, food processing or medical technology curricula, many of which are probably at least five to ten years out of date. If this is indeed the case, industry would logically be reluctant to hire these students, as they would have to provide a great deal of in-house training before the technician could function semi-independently. Companies working in highly competitive, rapidly emerging fields can rarely afford the resources to provide such training.

Observation of other high-tech industries has revealed that properly designed and implemented programs can be of great benefit to the industry. More highly trained individuals with BS or MS degrees seldom see technician positions as the end of their career ladders, and there is constant turnover in personnel as these people move on to other jobs. Two-year technicians provide stability in technician positions.

Acceptance of two-year technicians generally follows a pattern. Early in the development of a high-tech field, most of the work is accomplished by a highly educated "pioneer" work force. As the technology grows and matures, however, certain tasks are eventually "downgraded" and they become the responsibilities of competent but less highly trained technicians. At that point, the value of two-year technician training programs becomes evident. Such programs can be established with direct input from industry; their graduates are readily accepted in the work force and play significant roles there.

TASKS ACCOMPLISHED BY BIOTECHNICIANS

The survey identified the following knowledge/skills as being common to most biotechnicians.

- Prepare samples for various analyses including:
  - atomic absorption
  - chromatography
  - electrophoresis
  - spectroscopy
  - volumetric
- Prepare reagents and solutions. The technician must be able to calculate the quantity of each component needed to make the required amount of solution, use proper techniques in preparing the solutions and adjust the chemical properties such as normality or pH of the solution once it is made.
- Use appropriate, acceptable laboratory techniques required for any given task. This can include maintaining a sterile environment, properly disposing of waste materials, maintaining accurate and orderly laboratory records, etc.
- Set up laboratory apparatus.
- Collect samples. This is a very broad activity and can include the collection of entire organisms, some portion of an organism, some by-product of a process, etc.
- Analyze samples using a variety of biological and chemical techniques.
- Prepare culture media. Select the proper media for the organism to be cultured and prepare the media using appropriate laboratory techniques.
- Collect and process data. Take raw data from various analyses and perform calculations to put it in a usable form. Keep accurate records.
- Use a computer. Input data into a computer from a keyboard and use various software packages to get usable output. Includes the use of such software as spread sheets, word processing, and graphics packages.
- Operate laboratory equipment including:
  - spectrophotometers including visible and ultraviolet
  - centrifuges and ultracentrifuges
  - chromatography apparatus, particularly high-pressure liquid chromatographs and gas chromatographs
  - electrophoresis
  - balances
  - microscopes
  - autoclaves
  - sequencers and synthesizers for peptides, proteins and DNA
  - fermentation equipment
  - scintillation counters
  - lyophilizers

- Monitor and control temperature, pressure, level and flow for various biochemical processes using a variety of instruments ranging from simple probes to sophisticated automatic control systems.

In addition, most biotechnicians will specialize in one of the following areas:

- recombinant DNA techniques
- cell/tissue culture
- fermentation technology

Examples of skills specific to each of these areas are as follows:

Recombinant DNA

- Analyze proteins for composition, weight, amino acid sequence.
- Analyze polysaccharides for composition, weight and branching.
- Analyze DNA and RNA sequence.
- Purify protein product.
- Establish schedule and operate sequencing machines.
- Quantitate proteins, polysaccharides, DNA and RNA.

Cell/Tissue Culture

- Maintain microbial cultures.
- Select microbial strains.
- Establish plant and animal tissue culture lines.
- Maintain plant and animal tissue cultures.
- Innoculate cell cultures.
- Monitor growth conditions of cells.
- Harvest cells aseptically.
- Perform routine assays of final product to assess purity of the culture.
- Culture both procaryotic and eucaryotic cells.

Fermentation Technology

- Assist in the day-to-day operation of a fermentor in the manufacture of a given protein.
- Assist in the cloning of genes in cells.
- Assure that inoculations are correct.
- Monitor and adjust temperature, pH, and oxygen levels.
- Assay product to be sure it meets specifications.
- Keep precise records of process and product purity and yield.

These tasks should not be considered complete. The gross listings are intended only as a starting point for discussions between industry and schools. Developing an accurate job description for any position requires the cooperation of industry. The job description in this document is the first step. Detailed levels of task analyses should be done on the local level by schools establishing technician training programs to ensure that the needs of local industry are met.

MODEL CURRICULUM FOR TWO-YEAR BIOTECHNICIAN TRAINING PROGRAM

The curriculum proposed here is based on the task listings and suggestions from survey respondents. It is presented only as a first draft and requires careful scrutiny by both industry and academic institutions. Industry needs to determine whether this is indeed the background they are looking for in a technician, and schools need to tailor it to meet accreditation standards.

It should be kept in mind that this curriculum is designed to prepare entry-level biotechnicians for positions in the production area of a biotech company. The curriculum should also provide sufficient background so that, with a reasonable amount of work experience, the graduates can advance to positions with increasing responsibilities. The curriculum is not intended to make individuals proficient in every task that exists in the industry since each biotech company will use different processes, procedures, and equipment for accomplishing similar tasks. It is impossible to forecast the exact requirements of any individual company or to predict changing technology. The curriculum does provide a starting point that can be easily modified at the local area to maximize its value to local industry.

YEAR ONE

Quarter 1	Class	Lab	Total
Introduction to Biotechnology	2	4	6
Technical Math I - Algebra/Geometry	5		5
Chemistry I - Inorganic	3	3	6
Molecular and Cell Biology I	3	3	6
Technical Communications I	3		3
	16	10	26

Quarter 2			
Technical Math II - Statistics/Precalculus	5		5
Applied Physics I	3	3	6
Molecular and Cell Biology II	3	3	6
Chemistry II - Organic	3	3	6
Technical Communications II	3		3
	17	9	26

Quarter 3			
Principles of Microbiology	3	3	6
Biochemistry	3	3	6
Applied Physics II	3	3	6
Electronics	3	3	6
Elective	3		3
	15	12	27

YEAR TWO

Quarter 4	Class	Lab	Total
Industrial Microbiology	3	3	6
Computer Operations	1	5	6
Fundamentals of Instrumentation and Control	3	2	5
Analytical Chemistry	3	3	6
Fluid Power Devices	2	2	4
	12	15	27

12

Quarter 5			
Applied Genetics	3	3	6
Instrumental Analysis	2	3	5
Economics in Technology	3		3
Biotech Internship or Project		5	5
Mechanical Devices and Systems	2	2	4
Elective	3		3
	13	13	26

Quarter 6			
Protein Chemistry	3	3	6
Industrial Instrumentation	3	3	6
Industrial Relations	3		3
Biotech Project or Internship		5	5
Technical Elective	3	3	6
	12	14	26

Course Descriptions

Tentative course descriptions for each of the above courses are provided below.

Introduction to Biotechnology - Overview of the field and the various applications of biotechnology, and the steps required in producing a product through biotechnology, including research and development, licensing, etc. The lab will cover the care and handling of laboratory animals, sterile techniques, the use and care of common laboratory equipment such as balances, centrifuges, autoclaves, and incubators.

Chemistry I - Basic inorganic chemistry including safety, atoms, molecules, ions, nomenclature, atomic structure, chemical equations, periodic classification of elements, and bonding. Includes weekly laboratory activities.

Technical Math I - Designed to develop and update algebraic skills. Includes functions and graphs, exponents, radicals, linear equations, determinants, factoring, quadratics and various techniques for solutions of equations and systems of equations. Also included in the course are fundamental elements of geometry.

Technical Communications I - Reviews English grammar and composition skills.

Molecular and Cell Biology I - Introduces fundamentals of cell biology, including cellular, subcellular and molecular characteristics of cells. Covers procaryotic cells.

Technical Communications II - Provides the student with a working knowledge of communication techniques, procedures, and formats used in industry and business. The student learns accepted methods of describing devices and processes; of making oral and written technical presentations; and of using written manuals, guides, specifications, and vendor instructions. Most importantly the student is involved extensively in writing various technical reports and in preparing and delivering appropriate technical presentations.

Technical Math II (Statistics and Precalculus) - Covers basic statistical concepts, population statistics and derivatives and their applications.

Molecular and Cell Biology II - Covers molecular genetics, movement, energetics. Includes mechanisms of regulation and growth of eucaryotic cells.

Chemistry II - Covers principles of organic chemistry including nomenclature with emphasis on the properties of organic compounds of biochemical importance. Lab covers the identification of organic compounds by characteristic chemical reactions and by spectroscopy.

Applied Physics I - A practical approach to the teaching of basic physics of force, work, rate, momentum, resistance, and power. Students are shown, by classroom demonstration, how these concepts are applied to four energy systems -- mechnaical, fluid, electrical, and thermal. Students perform practical laboratory experiments that relate each concept to the four energy systems.

Principles of Microbiology - Elementatry principles of microbial and viral interrelationships, morphology and physiology.

Biochemistry - Covers cellular organization, structure, and properties of cellular components, enzymes, energetics, metabolism, biosynthetic pathways, molecular genetics, regulatory mechanisms and nutrition.

Applied Physics II - Builds on the foundation developed in Applied Physics I by presenting the concepts of energy, force transformers, energy convertors, transducers, vibrations and waves, time constants and radiation. Practical hands-on experience with devices common to many technologies is offered in the laboratory.

Electronics - Designed to provide students with a working knowledge of modern electronic devices and the circuits in which they are employed. Electronic devices covered include pn diodes, Zener diodes, pnp and npn trasistors, SCRs, unijunction transistors, J FETs, MOS FETs and integrated circuits containing these devices.

Fluid Power - Designed to provide the student with an overview of fluid power technology and a working knowledge of each of the components used in fluid power circuits. Hydraulic and pneumatic systems will be discussed. Topics presented will include fundamentals of fluid dynamics, conventional fluid circuits and fluid power components.

Computer Operations - Geared around the personal computer. The student learns computer terminology, the fundamentals of computer operation and how to load and use various types of software packages including word processing, spreadsheets, data bases and graphics. The basic concepts of programming such as branching, looping, arrays, functions, and subroutines are also reviewed.

Fundamentals of Instrumentation and Control - Covers the fundamentals of process control with emphasis on devices used to monitor temperature, pressure, level and flow. The function of the major components of automatic control systems are also discussed.

Industrial Microbiology - Covers the development and practice of industrial fermentation processes, chemical activities of microorganisms and methods of control, handling of cultures, and product purification and assays.

Analytical Chemistry - Teaches methods of chemical and instrumental analysis including potentiometric titration, specific ion electrodes, chromatography and UV, IR, and AA spectrophotometry.

Economics in Technology - Develops the techniques necessary to evaluate the economic impact and advantages of different production methods. It is a course designed to familiarize the student with analysis techniques that are necessary for accurate cost evaluation of specific projects. The conceptual format enables the student to apply the appropriate tools to a diversity of cost-related decisions.

Instrumental Analysis - Includes separation techniques, radiochemical analysis, electrochemistry, high-pressure liquid chromatography, and advanced spectroscopic techniques.

Applied Genetics - Provides a general overview of genetics and discusses in greater detail molecular mechanisms, gene transfer, recombination, gene conversion, gene fusion, suppression, and transpositions.

Mechanical Devices and Systems - Focuses on principles, concepts, and applications of various mechanisms encountered in various types of equipment. Such mechanisms include belt drives, chain drives, gears, linkages, valves, fans and blowers. The subject matter on mechanical components and systems covers operational principles, uses, maintenance, troubleshooting, and procedures for repair and replacement. The laboratory applications emphasize practical maintenance and installation of equipment and selection and specification of proper replacement components from manufacturers' catalogs.

Industrial Instrumentation - Covers the operation and control of production scale fermentors and associated equipment. Also covered are laboratory instruments required in the quality control aspects of fermentation.

Industrial Relations - Includes the study of the basis of human relations and the organization of individual and group behavior. Leadership, organization and social environments (including labor unions), career development, communications and group processes as well as selected operating activities are covered. Appropriate case problems are reviewed and discussed. Special emphasis is placed on typical industrial and business relationships in everyday situations.

Protein Chemistry - A study of the chemistry of proteins and enzymes. Laboratory activities emphasize methods for isolation, analysis, characterization and synthesis of proteins and enzymes.

Biotechnology Internship/Project - The student gains experience with real-world equipment and processes that cannot be duplicated in a school laboratory environment. If an internship is not possible, the student should be assigned a faculty advisor who can assist the student in choosing a problem and designing laboratory activities to work toward a solution.

Industry members of the Task Force Meeting felt that the Biotechnology Internship was critical to the project. They also felt that the internship might be a key element in making the AAS-degreed technician more competitive on the job market.

Tailoring the Model Curriculum

The model curriculum should be reviewed and refined following a process similar to that described for developing the biotechnician job description. Representatives from industry and education need to review and revise the curriculum at the local level to ensure it is relevant, current, and educationally sound.

The model curriculum can be easily tailored to meet the needs of the various applications by substituting appropriate courses for those courses shaded in the curriculum. For instance, by substituting courses in the microbiology of food spoilage, food preservation techniques and nutrition, the biotechnician would be better prepared to work for biotech companies in the food industry. By substituting courses in plant breeding, seed crop development, plant physiology, plant diseases etc, the student would be better prepared to work in agricultural biotech companies. The specific specialties should be decided by the individual school and industry representatives from the companies that will be hiring the graduates from the program.

OTHER SUPPORT FROM TWO-YEAR POSTSECONDARY INSTITUTIONS

Industry representatives at the Biotechnology Task Force on Education meeting were asked to think of ways that schools could help the biotechnology industry other than implementing a two-year degree program. They responded that first and foremost, the schools should work closely with the industry in their geographic area as needs will vary from company to company.

Industry representatives suggested that schools should consider implementing individual courses, and that these courses should be higher level, comprehensive courses for the continuing education of existing employees. Suggested subjects included immunology, microbiology, protein biochemistry and separation science, molecular biology, molecular genetics, programming, electronics, statistics, and population statistics. They also felt that adding courses with a biotechnology emphasis to other curricula would be beneficial. An example would be adding immunology and virology to a medical technology curriculum. Bioethics is another course that could be taught either in a biotech curriculum or as part of a related curriculum.

Industry representatives felt that two-year postsecondary institutions could greatly reduce public ignorance and often negative reaction to biotechnology products and processes such as genetic engineering and cloning. Schools could help in this way by providing biotechnology overview courses as part of the continuing education program or as electives for other programs.

When asked if seminars, workshops, and short courses would be of benefit, the industry representatives urged caution. They indicated that too many workshops and seminars are already available through professional organizations, industry and universities. They indicated that short-term learning situations can seldom provide the depth required for retraining biotechnicians. They did indicate that schools might want to consider providing facilities for use by industry for industry-sponsored workshops and short courses.

Career development and guidance was also identified by industry representatives as being an area where two-year postsecondary institutions can help. For instance, how does the student choose what area he/she wants to work in, and how does the student pursue that choice? Two-year institutions can help students answer questions such as these.

CONCLUSION

The findings of this study are based solely upon the responses of 86 biotech companies that responded to a survey with a total population of 242. Before the total need for biotechnicians throughout the country can be accurately predicted, however, the total number of biotech companies that currently exist must be determined. In addition, companies and institutions on the periphery of biotechnology need to be identified and considered. Hospitals, for example, use laboratory technicians; these technicians will need to be trained in biotechnology methods as new diagnostic tests using recombinant DNA become accepted. Other institutions and companies will need workers who are trained in various aspects of biotechnology, even though they may not need biotechnicians per se.

The model curriculum should be further refined and competencies should be developed for each of the specified courses. Courses for specialty areas should be defined and specialty course descriptions developed.

Based upon the biotech industry's present level of acceptance of biotechnicians from two-year training programs, approximately 200 graduates a year should be able to find placement from 1986 to 1995. This data suggests that some postsecondary schools should consider implementing

two-year biotechnician training programs. These programs should be initiated, however, with an awareness that the largest markets for two-year graduates, at least for awhile, will be found in California and the Northeast (Massachusetts, New York, New Jersey, Maryland) since these states have the highest density of biotechnology companies. Limited placements are possible in other parts of the country, however, and placement opportunities will expand as the industry expands.

Since biotechnology companies have little or no experience in employing two-year technicians who have been trained specifically for biotechnology, they have little awareness of the potential value of such technicians. Two-year postsecondary schools interested in establishing biotechnician training programs must accept the challenge of "educating" the biotech industry. Schools must help biotechnology companies understand that their work force needs will change as the industry matures and that two-year technicians can be prepared to fulfill a significant set of those needs. Schools must also convince companies that graduates of the two-year programs considered in this study will be broadly educated, flexible and highly competent.

APPENDIX A
WRITTEN SURVEY FORM

Center for Occupational Research and Development
601 C Lake Air Drive
Waco, Texas 76710

Please help the Center for Occupational Research and Development determine industry needs and training requirements for biotechnicians by completing this questionnaire and returning it in the attached envelope by October 18, 1985. All information provided will be strictly confidential.

Thank you for your time and assistance.

1. What is your company's main product/research area(s)? Please check all that apply.

____ HUMAN HEALTH CARE
- ____ Monoclonal antibodies
- ____ Vaccines
- ____ Enzymes
- ____ New and improved drugs
- ____ Drug delivery systems
- ____ Gene therapy for genetic disease
- ____ Interferon
- ____ Hormones
- ____ Other proteins
- ____ Diagnostics
- ____ Therapeutics
- ____ Other (Please specify.)_____

_____

____ AGRICULTURE/ANIMAL HEALTH
- ____ Food additives
- ____ New and improved plants
- ____ Vaccines
- ____ Fertilizers, microbial nitrogen fixation
- ____ Animal feed supplements
- ____ Pesticides/herbicides
- ____ Plant growth hormones
- ____ Other (Please specify.)_____

_____

____ ENERGY AND ENVIRONMENT
- ____ Biomass
- ____ Extraction/recovery of metals
- ____ Chemicals and solvents
- ____ Algal cultures for photobioreactors
- ____ Decomposition/detoxification of chemicals
- ____ Improved microbial systems for environmental control of air, water, and soil
- ____ Enhanced oil recovery
- ____ Hydrogen and CO_2 production
- ____ Other (Please specify.)_____

_____

____ FOOD
- ____ Preparation/processing
- ____ Preservation
- ____ Other (Please specify.)_____
- ____ Enhanced nutritional value
- ____ Additives

_____

2. What biotechnology techniques does your company use? Please check all that apply.

____ Recombinant DNA	____ Enzymology
____ Fermentation	____ Separation
____ Purification	____ Sequencing
____ Hybridoma/Cell Fusion	____ Synthesis
____ Cell/Tissue Culture	____ Other (Please list below.)

3. How long has your company been involved in biotechnology R & D and/or production?

____ Less than 2 years	____ 5 - 10 years
____ 2 - 5 years	____ More than 10 years

4. How many technicians and professional scientists does your company employ?

   a. Total number of professional scientists _____

   b. Total number of technicians _____

   c. How many of your PROFESSIONAL SCIENTISTS are involved in biotechnology RESEARCH and DEVELOPMENT? _____

   d. How many of your TECHNICIANS are working in biotechnology RESEARCH and DEVELOPMENT? _____

   e. How many of your PROFESSIONAL SCIENTISTS are involved in biotechnology PRODUCTION? _____

   f. How many of your TECHNICIANS are working in biotechnology PRODUCTION? _____

6. How has your need for technicians changed over the last two years?

Increased by ____ %	____ Remained constant
Decreased by ____ %	____ Don't know

7. Please give your best estimate of the expected total number of biotechnicians to be employed by your company in the future. The projected total should include the present number of biotechnicians plus new hires.

_____ in the year 1987. _____ in the year 1995.

_____ in the year 1990.

8. Rate the importance of the following abilities/aptitudes/characteristics to biotechnicians on a scale from 1 to 5. The highest importance is 5. (Circle the appropriate number.)

Broad-based technical knowledge	1	2	3	4	5
Works well in a team	1	2	3	4	5
Works well independently	1	2	3	4	5
Supervisory/management skills	1	2	3	4	5
Laboratory skills	1	2	3	4	5
Highly specialized in _____	1	2	3	4	5
_____					
_____ (Please identify subject areas)					
Experience in _____	1	2	3	4	5
_____					
_____					

9. How much math do biotechnicians require? Please check all that apply.

____ Basic math skills
____ Algebra
____ Geometry
____ Trigonometry
____ Precalculus
____ Calculus

10. What tasks do you expect a technician to be able to perform? Check all that apply.

____ Clean glassware
____ Prepare reagents/solutions
____ Prepare samples
____ Use a computer
____ Collect/process data
____ Use sterile techniques
____ Calibrate equipment (Please give examples.)_____
_____
____ Set up laboratory apparatus
____ Collect samples
____ Analyze samples
____ Program a computer
____ Interpret data
____ Prepare culture media

____ Operate equipment (Please give examples.)_____
_____

____ Maintain and make minor repairs of equipment (Please give examples.)
_____

____ Others (Please specify.)_____
_____
_____

11. What education level does your company expect of biotechnicians?

____ Ph. D. ____ M. S. ____ B. S. ____ A. A. S. ____ High School

12. Do you think that your company would be interested in hiring technicians who are graduates from 2-year postsecondary biotechnician training programs?

____ Yes ____ No ____ Uncertain

13. If you answered NO to question 12, why?_____

_____

_____

14. If you answered YES to question 12, when do you think 2-year postsecondary biotechnology programs will be needed?

____ Now	____ 5 - 6 years	____ 9 - 10 years
____ 1 - 2 years	____ 7 - 8 years	____ more than 10 years
____ 3 - 4 years		

15. If you answered YES to question 12, what subjects should be included in a 2-year postsecondary biotechnician training program?
PLEASE BE AS SPECIFIC AND COMPREHENSIVE AS POSSIBLE.

_____

_____

_____

_____

_____

_____

16. Would you be willing to meet with representatives from 10 two-year post-secondary institutions to discuss biotechnology, the need for technicians in biotechnology, and the skills/knowledge requirements for these technicians? ____ Yes ____ No ____ Maybe

17. Please use this space if you have further comments on the need for biotechnicians, biotechnician training requirements, and the role of 2-year postsecondary institutions in the emerging field of biotechnology. Use the back of the survey if you need additional space.

18. Your Name _____

Title _____

Company _____

Address _____

_____

Phone area code (____)_____extension_____

APPENDIX B
SURVEY REGIONS AND STATES

East	Surveys Mailed	Valid Responses
Connecticut	8	2
Delaware	2	1
Florida	1	2
Georgia	1	-
Maine	1	-
Maryland	12	5
Massachusetts	23	7
New Jersey	28	10
New York	20	5
North Carolina	4	3
Pennsylvania	10	2
Rhode Island	2	-
Virginia	1	1
Ontario	2	1
Middle		
Colorado	4	3
Illinois	14	3
Indiana	4	2
Iowa	3	1
Louisiana	2	-
Michigan	3	2
Minnesota	2	-
Missouri	3	1
Nebraska	1	-
New Mexico	2	1
Ohio	5	1
Oklahoma	2	1
Texas	3	1
Wisconsin	6	3
West		
California	66	19
Montana	1	1
Utah	1	1
Washington	5	3
Returned with no address		4

Distribution of Biotech Companies Surveyed

APPENDIX C
COMPANIES SURVEYED BY STATE

California

3M Diagnostics Systems	Mountain View,	CA
AMGen	Thousand Oaks,	CA
ARCO Plant Cell Res Inst	Dublin,	CA
Advanced Biotechnology Assoc	San Francisco,	CA
Advanced Genetic Sciences, Inc	Oakland,	CA
Advanced Genetics Research Inst	Berkeley,	CA
Alpha Therapeutic Corp	Los Angeles,	CA
American Diagnostics Corp	Newport Beach,	CA
American Qualex	La Mirada,	CA
Animal Vaccine Research Corp	La Jolla,	CA
Astra Scientific	Santa Clara,	CA
Axonics	Mountain View,	CA
Bio-Response, Inc	Hayward,	CA
Bio-Separations Consultants	Long Beach,	CA
Bio-con, Inc	Bakersfield,	CA
BioGenex Laboratories	Dublin,	CA
Calgene, Inc	Davis,	CA
California Biotechnology, Inc	Mountain View,	CA
Cetus Corporation	Emeryville,	CA
Cetus Immune Corp	Palo Alto,	CA
Chiron Corporation	Emeryville,	CA
Clonal Research	Newport Beach,	CA
Codon	Brisbane,	CA
Collagen, Inc	Palo Alto,	CA
Cooper-Lipotech, Inc	Menlo Park,	CA
Cutter Laboratories, Inc	Emeryville,	CA
DNAX Corporation	Palo Alto,	CA
DNAX Research Institute	Palo Alto,	CA
EnBio, Inc	Fairfield,	CA
Fermentec Corporation	Los Gatos,	CA
Fluor Corporation	Irvine,	CA
Genencor	South San Francisco,	CA
Genentech, Inc	South San Francisco	CA
Genetic Replication Tech, Inc	Newport Beach,	CA
Hana Biologics, Inc	Berkeley,	CA
Hybritech, Inc	San Diego,	CA
Hytech Biomedical, Inc	Berkeley,	CA
Immulok, Inc	Carpinteria,	CA
Immunetech, Inc	La Jolla,	CA
International Genetic Eng, Inc	Santa Monica,	CA
Liposome Technology, Inc	Menlo Park,	CA
McLellan & Copenhagen, Inc	Cupertino,	CA
Molecular Biosystems, Inc	San Diego,	CA
Monoclonal Antibodies, Inc	Mountain View,	CA
Mycogen Corporation	San Diego,	CA
Ocean Genetics	Tiburon,	CA
Phyto-tech Lab	Torrance,	CA
Phytogen	Pasadena,	CA
Plant Genetics, Inc	Davis,	CA
Quidel Home	La Jolla,	CA
Replicon	South San Francisco,	CA

Salk Inst Biotech/Ind Assoc, Inc	La Jolla,	CA
Standard Oil Co of California	San Francisco,	CA
Sungene Technologies Corp	Palo Alto,	CA
Synbiotex Corporation	San Marcos,	CA
Synbiotics	San Diego,	CA
Syncor Intertational	Sylmar,	CA
Syntex Research	Palo Alto,	CA
Syntro Corporation	San Diego,	CA
Syva Company	Palo Alto,	CA
Techniclone Int'l Corp	Santa Ana,	CA
Triton Biosciences, Inc	Alameda,	CA
Xertex Corporation	Santa Fe Springs,	CA
Xoma Corporation	San Francisco,	CA
Zoecon	Palo Alto,	CA
Zymed Laboratories, Inc	South San Francisco,	CA
Colorado		
Agrigenetics Research Corp	Boulder,	CO
General Genetics	Golden,	CO
Synergen, Inc	Boulder,	CO
Syngene Products & Res, Inc	Fort Collins,	CO
Connecticut		
Genzyme	Norwalk,	CT
John Brown Engs & Constructors	Stamford,	CT
Molecular Diagnostics	West Haven,	CT
Novo Laboratories, Inc	Wilton,	CT
Stauffer Chemical Company	Westport,	CT
Technology Management Group	Stamford,	CT
University Genetics Company	Westport,	CT
Xenogen, Inc	Storrs,	CT
Delaware		
E I Du Pont de Nemours & Co	Wilmington,	DE
Florida		
Microlife Technics	Sarasota,	FL
Georgia		
Hybridoma Sciences, Inc	Tucker,	GA
Iowa		
Ambico, Inc	Dallas Center,	IA
Diamond Laboratories	Des Moines,	IA
Pioneer Hi-Bred Int'l, Inc	Johnston,	IA
Illinois		
Abbott Laboratories	North Chicago,	IL
CPC International	Summit,	IL
Dart & Kraft, Inc	Northbrook,	IL
Davy McKee Corporation	Chicago,	IL
DeKalb Pfizer Genetics	DeKalb,	IL
Enzyme Bio-Systems, Ltd	Argo,	IL
Petrogen, Inc	Arlington Heights,	IL
G D Searle Company	Skokie,	IL
A E Staley Mfg Company	Decatur,	IL

Standard Oil Co of Indiana	Naperville,	IL
TPM Strategic Planners, Inc	Lake Forest,	IL
Travenol Laboratories, Inc	Round Lake,	IL
U O P, Inc	Des Plaines,	IL
Ultraferm, Inc	Wheeling	IL
Indiana		
Eli Lilly & Company	Indianapolis,	IN
Indiana BioLab	Palmyra,	IN
Int'l Minerals & Chemical Corp	Terre Haute,	IN
Miles Laboratories, Inc	Elkhart,	IN
Louisiana		
Ethyl Corporation	Baton Rouge,	LA
Imreg, Inc	New Orleans,	LA
Massachusetts		
American Biodesign, Inc	Newton,	MA
Amicon Division, W R Grace	Danvers,	MA
Angenics	Cambridge,	MA
BTC Diagnostics, Inc	Cambridge,	MA
Biogen	Cambridge,	MA
Biogen, Inc	Cambridge,	MA
Biotechnica International, Inc	Cambridge,	MA
Cambridge Bioscience Corp	Framingham,	MA
Collaborative Research, Inc	Lexington,	MA
Damon Biotech, Inc	Needham Heights,	MA
Dynatech R&D Company	Cambridge,	MA
Genetics Institute	Brookline,	MA
Genetics Institute	Cambridge,	MA
Integrated Genetics, Inc	Framingham,	MA
Ionics, Inc	Watertown,	MA
Arthur D Little, Inc	Cambridge,	MA
New England Biolabs	Beverly,	MA
New England Nuclear Corp	Newton Center,	MA
Repligen Corporation	Cambridge,	MA
Serono Laboratories, Inc	Randolph,	MA
Swartz Associates	Winchester,	MA
The Nest Group	Southboro,	MA
Maryland		
Bethesda Research Labs, Inc	Gaithersburg,	MD
Biotech Research Labs, Inc	Rockville,	MD
Crop Genetics International	Dorsay,	MD
Diagnon Corporation	Laurel,	MD
Electro-Nucleonics	Columbia,	MD
Genetics International, Inc	Boston,	MD
Genex	Rockville,	MD
Genex Corporation	Rockville,	MD
W R Grace & Co	Columbia,	MD
Hem Research	Rockville,	MD
IGI Biotechnology, Inc	Columbia,	MD
Litton Bionetics	Kensington,	MD
Martin Marietta	Baltimore,	MD
Organon Teknika	Kensington,	MD

Maine		
Atlantic Antibodies	Scarborough,	ME
Michigan		
Dow Chemical Company	Midland,	MI
Neogen Corporation	East Lansing,	MI
The Upjohn Company	Kalamazoo,	MI
Minnesota		
C3 International	Roseville,	MN
Molecular Genetics, Inc	Minnetonka,	MN
Missouri		
Invitron Corporation	Clayton,	MO
Mallinckrodt, Inc	St Louis,	MO
Monsanto Company	St Louis,	MO
Montana		
Ribi Immunochem Research, Inc	Hamilton,	MT
North Carolina		
Becton Dickinson & Company	Research Triangle Park,	NC
CIBA-GEIGY Corp	Research Triangle Park,	NC
GIST-BROCADES USA, Inc	Charlotte,	NC
Wellcome Research Laboratories	Research Triangle Park,	NC
Nebraska		
Norden Laboratories, Inc	Lincoln,	NE
New Jersey		
Allied/Signal Corporation	Morristown,	NJ
American Cyanamid	Princeton,	NJ
Applied Genetics, Inc	New Brunswick,	NJ
Campbell Soup Company	Camden,	NJ
Celanese Research Company	Summit,	NJ
Cytogen Corporation	Princeton,	NJ
DNA Plant Technology	Cinnaminson,	NJ
Ecogen, Inc	Lawrenceville,	NJ
Exxon Research & Engineering Co	Florham Park,	NJ
FMC Corporation	Princeton,	NJ
Hoffmann-LaRoche, Inc	Nutley,	NJ
Interferon Sciences, Inc	New Brunswick,	NJ
Johnson & Johnson	New Brunswick,	NJ
Lederle Laboratories	Wayne,	NJ
Merck & Company, Inc	Rahway,	NJ
Nabisco, Inc	East Hanover,	NJ
New Brunswick Scientific Co	Edison,	NJ
Organon, Inc	West Orange,	NJ
Ortho Pharmaceutical Corp	Raritan,	NJ
Pharmacia, Inc	Piscataway,	NJ
Sandoz Corporation	East Hanover,	NJ
Schering-Plough Corp	Kenilworth,	NJ
E R Squibb & Sons, Inc	Princeton,	NJ
Stone & Webster Eng Corp	Cherry Hill,	NJ
Sybron Biochemical	Birmingham,	NJ
The Liposome Co, Inc	Princeton,	NJ

Unigene Laboratories, Inc	Fairfield,	NJ
Worne Biotechnology, Inc	Medford,	NJ
New Mexico		
Advanced Mineral Technologies	Socorro,	NM
Summa Medical Corporation	Albuquerque,	NM
New York		
Actagen	New York,	NY
Bio-Technology General Corp	New York,	NY
Brain Research	New York,	NY
Bristol-Myers Company	Syracuse,	NY
Cellorgan International, Inc	New York,	NY
Chemap, Inc	Woodbury,	NY
Diagnostic Technology, Inc	Hauppauge,	NY
Eastman Kodak Company	Rochester,	NY
Enzo Biochem, Inc	New York,	NY
General Electric Company	Schenectady,	NY
General Foods Corporation	Tarrytown,	NY
Genetic Diagnostics Corporation	Great Neck	NY
IBM Corporation	Yorktown Heights,	NY
Int'l Genetic Sciences Partnership	Jamaica,	NY
Lifecodes Corporation	Elmsford,	NY
National Distillers & Chem Co	New York,	NY
Nuclear & Genetic Technology	Deer Park,	NY
Oncogene Science, Inc	Mineola,	NY
Pfizer, Inc	New York,	NY
Ohio		
Enzyme Technology Corp	Ashland,	OH
T R Evans Research Center	Painesville,	OH
Nutrisearch Company	Cincinnati,	OH
SDS Biotech Corporation	Painesville,	OH
SOHIO Research Center	Cleveland,	OH
Oklahoma		
Celtek, Inc	Norman,	OK
Phillips Petroleum Company	Bartlesville,	OK
Ontario		
Allelix, Inc	Mississauga,	ON
University of Waterloo	Waterloo,	ON
Pennsylvania		
Biochem Technology, Inc	Malvern,	PA
Biological Energy Corp	Valley Forge,	PA
Centocor	Malvern,	PA
Cooper Diagnostics, Inc	West Chester,	PA
Cytox Corporation	Allentown,	PA
PPG Industries	Pittsburgh,	PA
Polybac Corporation	Allentown,	PA
Rohm and Haas Company	Spring House,	PA
SmithKline Beckman	Philadelphia,	PA
Stearns Catalytic Corp	Philadelphia,	PA

Rhode Island		
New Eng Monoclonal Resources	Providence,	RI
Separations Technology, Inc	Wakefield,	RI
Texas		
Aqua-Terra Biochemical Corp	Lancaster,	TX
Frito-Lay, Inc	Dallas,	TX
Kallestad Laboratories	Austin,	TX
Utah		
NPI	Salt Lake City,	UT
Virginia		
Meloy Laboratories, Inc	Springfield,	VA
Washington		
Endorphin, Inc	Seattle,	WA
Genetic Systems Corporation	Seattle,	WA
Immunex Corporation	Seattle,	WA
Oncogen	Seattle,	WA
Zymogenetics, Inc	Seattle,	WA
Wisconsin		
Agracetus	Middleton,	WI
Agrigenetics Corporation	Madison,	WI
Bio-Technical Resources, Inc	Manitowoc,	WI
Dairyland Foods Corp	Waukesha,	WI
Miller Brewing Company	Milwaukee,	WI
Universal Foods Corporation	Milwaukee,	WI

APPENDIX D
BIOTECHNOLOGY TASK FORCE ON EDUCATION

Industry Representatives

American Cyanamid
Dr. Ron Stotish, Group Leader,
Chemotherapy Immunology Department

AMGen
Dr. William F. Puchlevic
Personnel Manager

Ms. Susanne Hirsch

Aqua-Terra Biochemical Corporation
of America, Inc.
Mr. Walter Adams
Plant Manager

Bio-Technical Resources, Inc.
Mr. James A. Donchek
Executive Vice President

CIBA-GEIGY
Ms. Sandra Michaux
Human Resource Specialist

Damon Biotech, Inc.
Ms. Kathy Fay
Director of Personnel

Eastman Kodak Company
Mr. Jim Shepler

Gen-Care Bio-Medical Corporation
Dr. Dennis M. Todd
President

Genencor
Ms. Linda Fitzpatrick
Staffing Manager

Gist-Brocades
Dr. Tom Wallace
Applications Lab Manager

Immunex Corporation
Dr. Christopher S. Henney
Executive Vice President and
Science Director

Industrial Biotechnology Association
Ms. Susan G. Racca
Associate, Special Projects

Interferon Sciences, Inc.
Dr. Donna R. Fugit,
Assistant to the Vice President,
Research

Molecular Biosystems
Mr. Vincent Frank
President

Monsanto Company
Dr. Michael J. Montague
Operations Manager

Mycogen Corporation
Dr. Jerry Caulder
President and CEO

Nutrisearch Company
Mr. Gerald A. Levine
President

Oncogen
Ms. Thea Stone
Director of Personnel

Petrogen, Inc.
Dr. John J. Kilbane
Senior Research Scientist

Pioneer Hi-Bred International, Inc.
Dr. Nicholas M. Frey
Director, Biotechnology Research

Sandoz Corporation
Dr. Robert H. Zaugg
Assistant Director, Technology
Assessment

Travenol Laboratories, Inc.
Dr. John A. Thomas
Vice President for Corporate
Research

University Genetics Company
Mr. Donald J. Silvert
Director of Scientific Affairs/CSO

School Representatives

Colorado State Board of Community Colleges and Occupational Education
Dr. Daniel C. Fahrlander
Director, Larimer County Vo-Tech Center

Cuyahoga Community College
Mr. Cullen Johnson
Associate Dean
Health Careers and Natural Science

Des Moines Area Community College
Dr. Jerry Moskus, Executive Vice President of Educational Services

Eastern Iowa Community College Dist
Scott Community College
Mr. John Baker, Associate Director of Institutional Research, and Telecommunications Director

Ms. Jan Friedel, Associate Vice Chancellor for Education

Georgia Board of Postsecondary Vocational Education
Ms. Patt Stonehouse
Coordinator, Program Improvement

Lorain County Community College
Mr. Robert Schloss, Chairman
Division of Health Careers

Macomb Community College
Dr. Daniel A Jaksen
Director of Planning and Evaluation

North Central Technical Institute
Dr. Charles Christianson
Assistant Director

Sinclair Community College
Dr. Ned Sifferlen
Vice President for Instruction
Mr. Herman Brant, Dean of Allied Health Technologies Division

Texas State Technical Institute
Mr. Lovell A. Pillow, Manager
Management Information Services

Triton College
Dr. Ernest R. Leach
Vice President for Academic Affairs

APPENDIX E
SPECIFIC PRODUCTS/RESEARCH AREAS

Human Health Care

	East	Middle	West	USA
Monoclonal antibodies	43%	28%	44%	40%
Vaccines	18%	17%	24%	20%
Enzymes	28%	28%	16%	24%
New and improved drugs	18%	22%	24%	21%
Drug delivery systems	23%	28%	12%	20%
Gene therapy for genetic disease	3%	0%	0%	2%
Interferon	8%	0%	16%	8%
Hormones	10%	11%	28%	15%
Other proteins	20%	17%	40%	24%
Diagnostics	58%	11%	44%	44%
Therapeutics	25%	17%	44%	29%
Others	13%	6%	4%	8%

Agriculture and Animal Health

	East	Middle	West	USA
Food additives	8%	39%	4%	13%
New and improved plants	23%	44%	16%	24%
Vaccines	10%	17%	20%	15%
Fertilizers, microbial nitrogen fixation	18%	28%	12%	17%
Animal feed supplements	18%	28%	4%	15%
Pesticides/herbicides	28%	22%	20%	23%
Plant growth hormones	13%	11%	4%	9%
Other	13%	17%	4%	12%

Energy and Environment

	East	Middle	West	USA
Biomass	13%	11%	0%	8%
Extraction/recovery of metals	8%	6%	4%	6%
Chemicals and solvents	13%	22%	12%	14%
Algal cultures for photobioreactors	0%	6%	0%	1%
Decomposition/detoxification of chemicals	25%	11%	4%	15%
Improved microbial systems for environmental control of air, water and soil	13%	11%	8%	11%
Enhanced oil recovery	5%	17%	4%	7%
Hydrogen and CO_2 production	3%	0%	0%	1%
Other	0%	6%	4%	2%

Food

	East	Middle	West	USA
Preparation/processing	18%	6%	4%	11%
Preservation	5%	0%	8%	5%
Enhanced nutritional value	10%	22%	4%	11%
Additives	8%	17%	4%	8%
Other	10%	6%	4%	8%

APPENDIX F
AREAS OF SPECIALIZATION

Biochemistry (5)
Biology (1)
Cell biology (2)
Cell culture (1)
Chemical engineering (1)
Chemistry (4)
Cloning (2)
Chromatography (2)
Genetics including cytogenetics, animal, molecular, and plant (4)
Electron microscopy (1)
Electrophoresis (2)
Enzyme-linked immunosorbent assay (1)
Fermentation (1)
High-pressure liquid chromatography (1)
HLA (1)
Immunology (4)
Intelligence (1)
Lab instrumentation (2)
Lipid chemistry (1)
Manual dexterity (1)
Math (1)
Media preparation (1)
Microbiology (4)
Molecular biology (2)
Monoclonals (1)
Nucleic acid chemistry (1)
Physiology (1)
Plant biology (2)
Plant tissue culture (4)
Process engineering (1)
Protein chemistry (5)
Radioimmunoassay (1)
Recombinant DNA (3)
RNA (1)
Spectroscopy (1)
Thinking (1)
Tissue culture (1)
Transformation techniques (1)
Virology (1)

APPENDIX G
AREAS OF EXPERIENCE

The surveyed companies stated that they look for biotechnicians with experience in one or more of the following:

Accounting (1)
Biochemistry (7)
Biology (7)
Biology, cell (4)
Biology, micro (6)
Biology, molecular (2)
Chemical engineering (1)
Chemistry (6)
Chemistry and metallurgy (1)
Chemistry and microbiology (2)
Cloning (1)
Computer operation (1)
Culture collection (1)
DNA sequencing (3)
Enzymology (1)
Fermentation (1)
Gas chromatography (1)
Genetics (4)
High-pressure liquid chromatography (1)
Immunoassays (1)
Immunochemistry (1)
Immunology (4)
Instrumental analysis (1)
Isolation of new strains (1)
Isotope usage (1)
Lab procedures (4)
Lab equipment usage (2)
Lipid chemistry (1)
Management (1)
Math skills (1)
Pharmacology (1)
Process engineering (1)
Protein chemistry (4)
Recombinant DNA (1)
Sterile techniques (1)
Tissue culture (3)
Virology (1)
Working with high accuracy (1)

APPENDIX H
EQUIPMENT LISTINGS

The technician must operate the following equipment:

Air blowers (1)
Air compressors (1)
Analytical equipment (1)
Atomic absorption (1)
Autoanalyzers (1)
Autoclaves (5)
Balances (6)
Beta counters (2)
Boilers (1)
Carbon dioxide analyzers (1)
Centrifuges (18)
Centrifuges, ultra (6)
Chromatography apparatus (3)
Chromatography, column (1)
Chromatography, gas (6)
Chromatography, high-pressure liquid (15)
Computers (4)
Conductivity meters (2)
DNA sequencers (3)
DNA synthesizers (1)
Electrophoresis (11)
Equipment, standard lab (7)
Equipment, highly specialized (1)
Equipment, proprietary scale-up (1)
Fermentation equipment (8)
Fluorometers (1)
Fraction collectors (4)
Gamma counters (3)
Gelometers (1)
Gene machines (1)
Hand tools (1)
Incubators (2)
Lyophilizer (3)
Membrane equipment for separation (1)
Microscopes (5)
pH meters (11)
pH titration equipment (1)
Peptide sequencers (1)
Peptide synthesizers (1)
Pilot brewing (1)
Pipettors (2)
Polarimeters (1)
Printing presses (1)
Protein sequencers (1)
Protein synthesizers (1)
Pumps (1)
Refractometers (1)
Run gels (1)
Scanners (1)
Scintillation counters (2)
Spectrophotometers (24)
Spreadsheet programs (1)

The technician should calibrate the following equipment:

Balances (5)
Carbon dioxide analyzers (1)
Carbon dioxide incubators (1)
Centrifuges (2)
Chromatographs, gas (6)
Chromatographs, high-pressure liquid (12)
Chromatography apparatus (2)
Conductivity meters (3)
Dissolved oxygen probes/meters (2)
DNA sequencers (2)
Fermentation tanks (1)
Fermentors, bench (1)
Flow meters (1)
Foam controllers (1)
Fraction collectors (1)
Incubators (1)
Lab equipment, basic (3)
pH meters (14)
pH titration equipment (1)
Peptide sequencers (1)
Pipettors (4)
Process control equipment (1)
Pumps (3)
Radiation counters (2)
Samplers (1)
Scintillation counters (2)
Spectrophotometers (14)
Temperature-control baths (1)
Thermocouples (1)
Volumetric equipment (1)

The technician should be able to maintain and repair the following equipment:

Air pumps (1)
Autoclaves (2)
Balances (3)
Boilers (1)
Bulb changes (1)
Centrifuges (5)
Chromatographic systems (2)
Chromatographs, high-pressure liquid (4)
Colorimeters (1)
Conductivity meters (2)
Dissolved-oxygen probes/meters (1)
Electric pumps and motors (1)
Electrophoretic systems (1)
Equipment, standard lab (3)
Fermentors (3)
Fraction collectors (1)
Grinding and classifying equipment (1)
Incubators (4)
Microscopes (3)
pH meters (5)
Peptide synthesizers (1)
Pipettors (2)
Piping changes (1)
Printing presses (1)
Pumps (2)
Spectrophotometers (5)
Waterbaths (1)

The technician should maintain equipment only, not repair it. (5)

APPENDIX I
REASONS STATED FOR NOT HIRING TWO-YEAR STUDENTS

Students with post high school training would be used as lab aides in the dishroom/sterilization facility or the media facility but not as research assistants in R & D.

They lack research experience. They need to know about research and prove their skills and interest in understanding the project, interpreting data, etc.

Lack of education in basic biological sciences and a narrow background geared toward biotechnology.

We want broadly educated individuals as opposed to people with delta function mechanical skills.

Our program is exploratory. We need flexible staff members since we cannot know which areas (and thus skills) will pan out for us.

Looking for BS/MS-level lab and course training in biology.

Prefer college-level coursework and laboratory skills in our basic research environment.

There are plenty of well-trained BS people available at reasonable salaries.

We prefer that our technicians have the flexibility that results from a broad background of scientific training as well as the research environment training that the university can provide.

The company is very fast-paced and there is not time to train people--we prefer to hire experienced, smart individuals.

Capable people get their best experience in an active research lab.

People with BS degrees and above are usually more mature and well-rounded. Also, there is an oversupply of BS and above available. In fact, we usually find enough MS-level and above for hiring needs.

Not enough depth and basic understanding/skills in biological subjects.

Lab space is limited.

Our technicians are used at a high level and have comprehensive training.

Current saturation of bioengineers with PhD and no experience or true creative ability.

Insufficient training.

At present we expect independent work on assigned projects. This includes troubleshooting, interpretation of own data and planning future experiments independently.

We feel strongly about technicians holding a BS degree as a minimum because we anticipate intellectual input from all staff--our small size with respect to work load necessitates this.

Related Comments

So far, our biotechs have been trained by senior scientists in culture growing, extraction and purification methods. Basic laboratory "sterile" procedures would be a prerequisite--all of our biotechs are thoroughly trained in-house in this area, but it should be emphasized in a biotech training program. Two-year programs would be very helpful to save some time in on-the-job training in basic lab skills.

There is a probable need for detail-oriented technicians to perform routine analytical tests (QA/QC), keep accurate records/files for FDA, care for lab animals, maintain "clean room"/sterile processing area.

Research: It may be difficult for an associate degree to compete with BS/MS personnel. An AAS would have to show superior qualities or be trained in a very specific area to stand out. General prejudices (especially in academics; not so much in industry) might preclude AAS people from consideration (we do not). Salaries might be lower for AAS compared to BS/MS even though work would be the same. Acceptance of lower salaries might make them more competitive, but I'm only guessing. Production: The situation for production personnel, I suspect, would be different and greater opportunities would exist for AAS degree holders. The big thing regardless of research or production is to get one's foot in the door and let abilities speak for themselves.

The training process for biotechnicians is expensive (particularly cell culture techniques), should be done by people active in research (which the two-year institute is rarely able to provide), and requires more facilities than the two-year institution can provide.

Even though biotechs require specialized skill, a conscientious individual with one or two years of training can carry out many procedures in the production phase.

For the most part, experience is more important than education. If the postsecondary education was concentrated and diversified to equate to real-work experience, it would be important.

It is difficult for me to imagine that a two-year program would be sufficient training for a research technician in the area of recombinant DNA technology.

We do much of our research on contract and it does not show up on this survey.

We purchase approximately two million dollars of basic research per year. Translation of basic research into products takes dedicated skill and care and maturity. We cannot afford to pay for 10 years of an individual's growth. We do not have to pay. There is a high supply of trained individuals.

We find a relative abundance of qualified individuals at the Bachelors level for our entry openings in R & D. The apparent need for biotechnicians below the Bachelor's level of training would be in sophisticated production.

We have a number of repetitious laboratory jobs filled by BS-level persons who are overqualified. AAS-level persons who could be easily trained would probably be useful.

I think there is at this time, only a limited need for biotechs except in large centers for this kind of work, eg., California & Massachusetts. The jobs are not that plentiful to encourage students in large numbers to get this kind of training.

Biotechnicians need some formal training beyond that normally received by average high school students. Much of the training can be obtained on the job and at night classes, but postsecondary training would be desirable before the technician takes the job.

Skills necessary depend on specific job, and I don't see how you can give training sufficient to accommodate so many different possible roles.

Biotechnology is a fast-moving field and it is essential that the people working in the area are versatile.

As biotechnology companies bring more and more products and technologies to "market" the need for biotechnicians will become greater. As production processes increase, more routine and semi-routine job functions will need to be accomplished--and technicians with associate degrees and scientific lab experience will fit the requirements.

Believe the need for two-year postsecondary biotechnicians in biotechnology production may be greater than in a research-oriented environment.

Have many locally available BS/MS spouses seeking part-time employment. Don't need other sources.

This survey is difficult to complete in the context of our company--it is not clear what the definition of biotechnician is: we have people working at all levels. Only people in manufacture/production and glassware washing would currently be hired without a bachelor's degree.

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